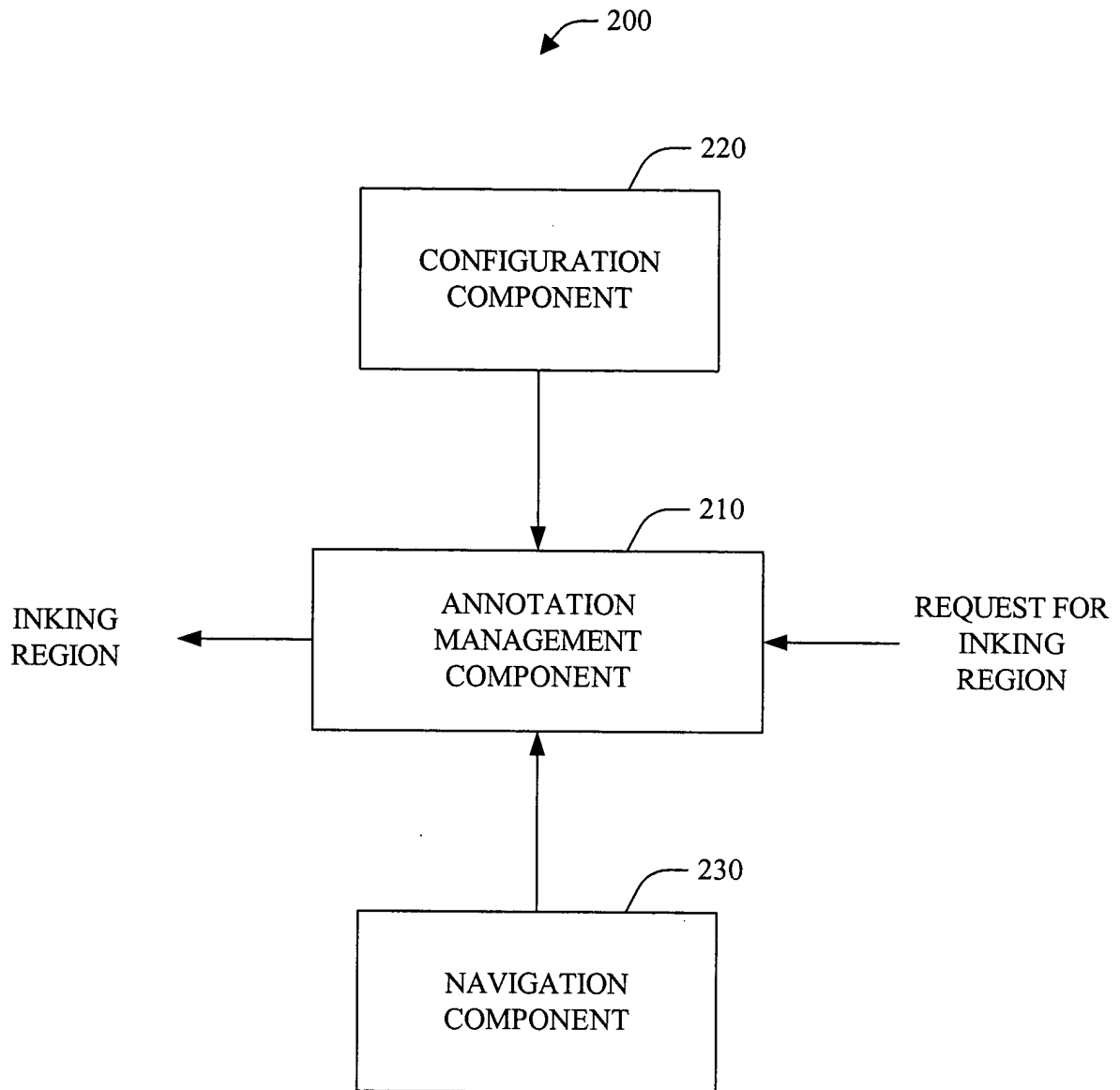
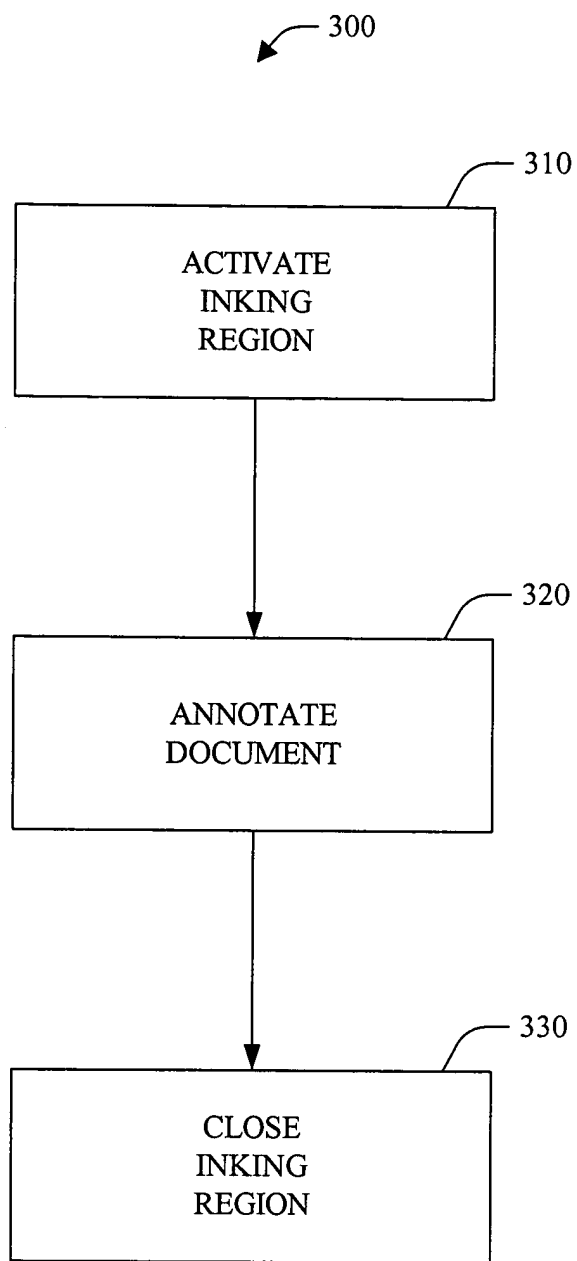


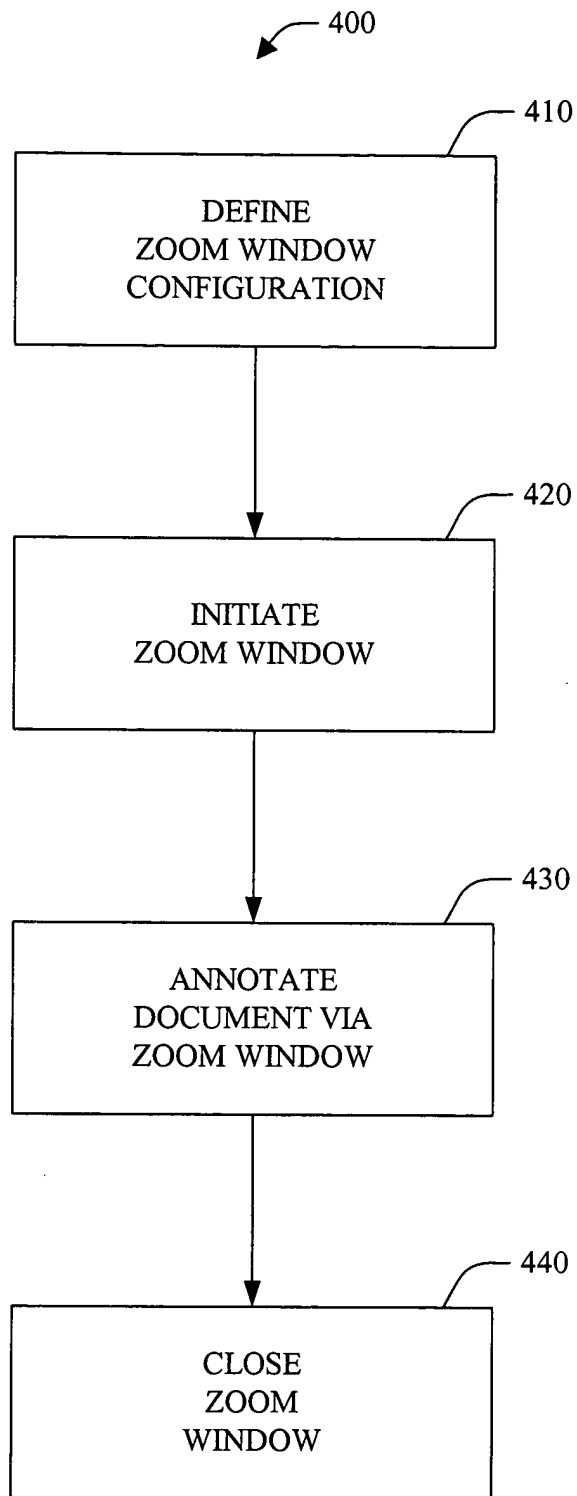
**FIG. 1**



**FIG. 2**



**FIG. 3**



**FIG. 4**

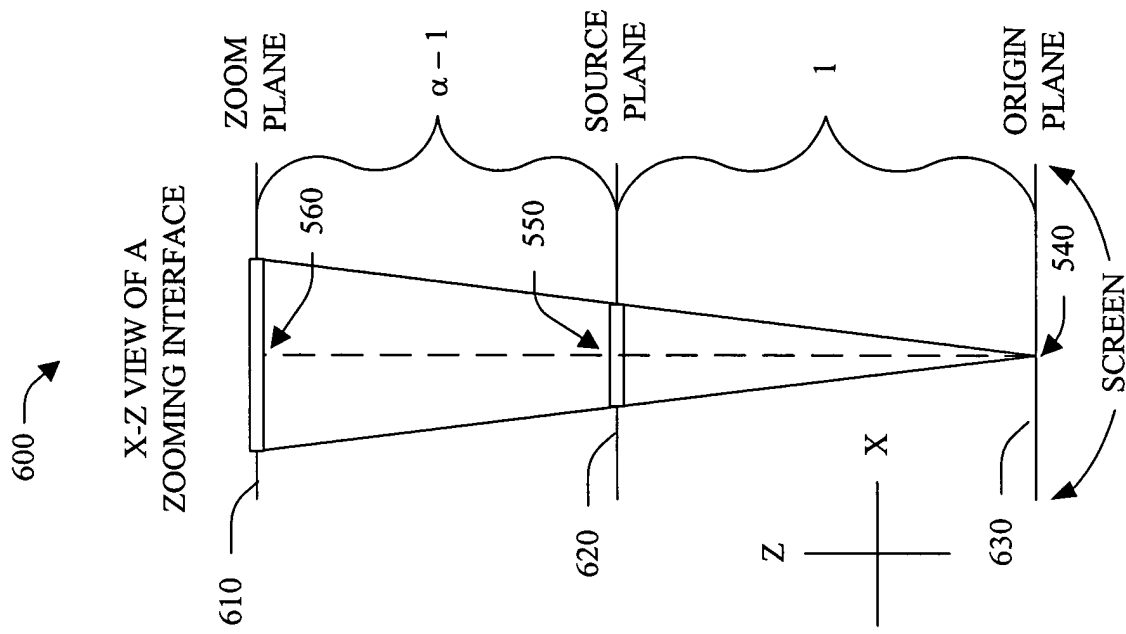


FIG. 6

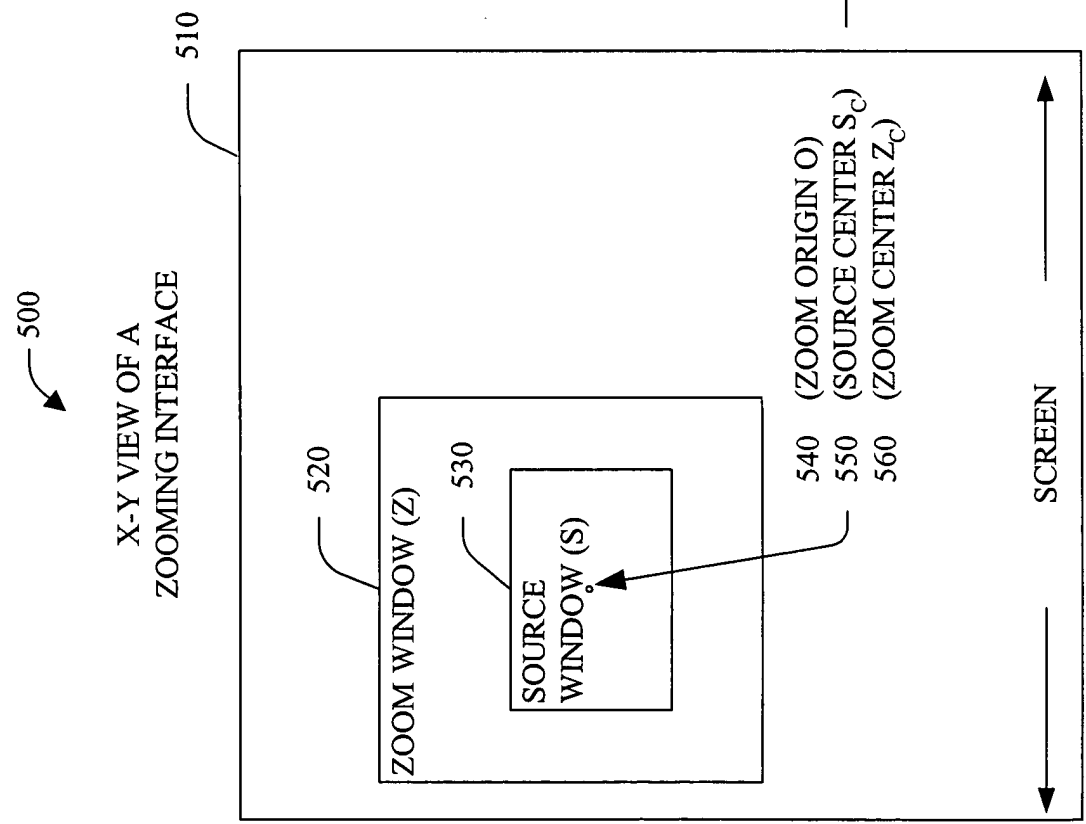
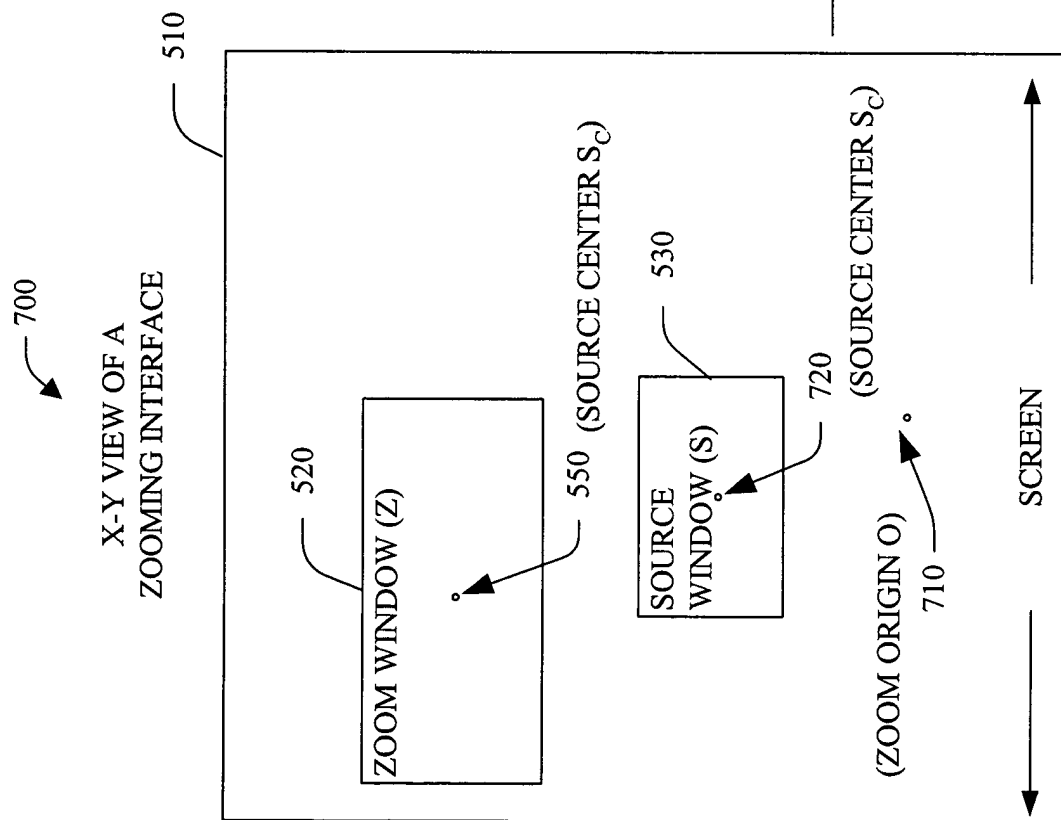
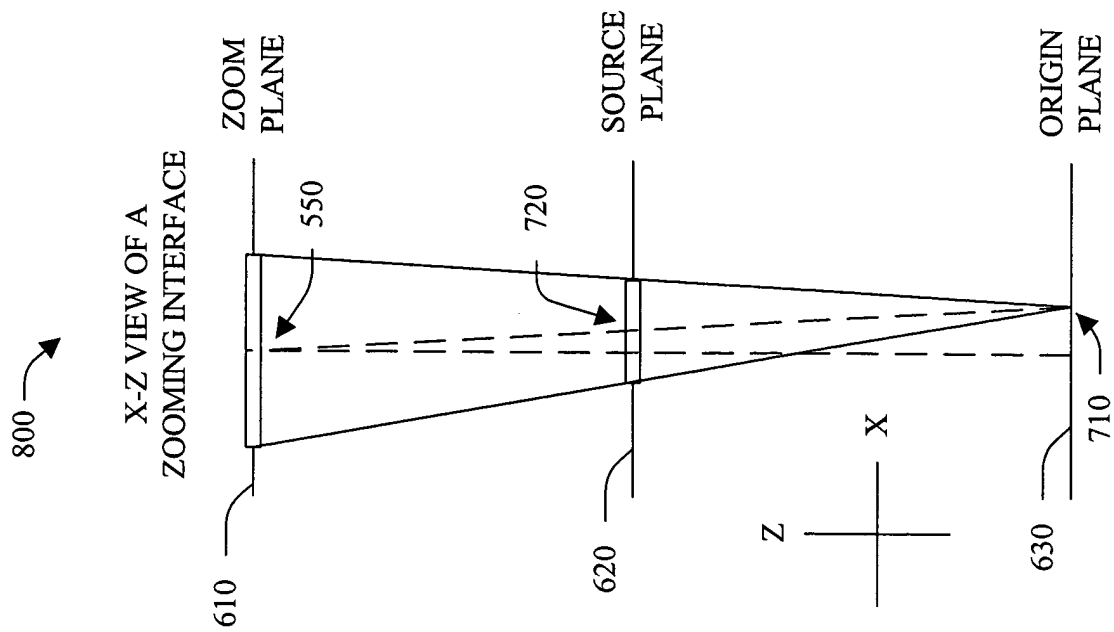


FIG. 5



**FIG. 7**

**FIG. 8**

900

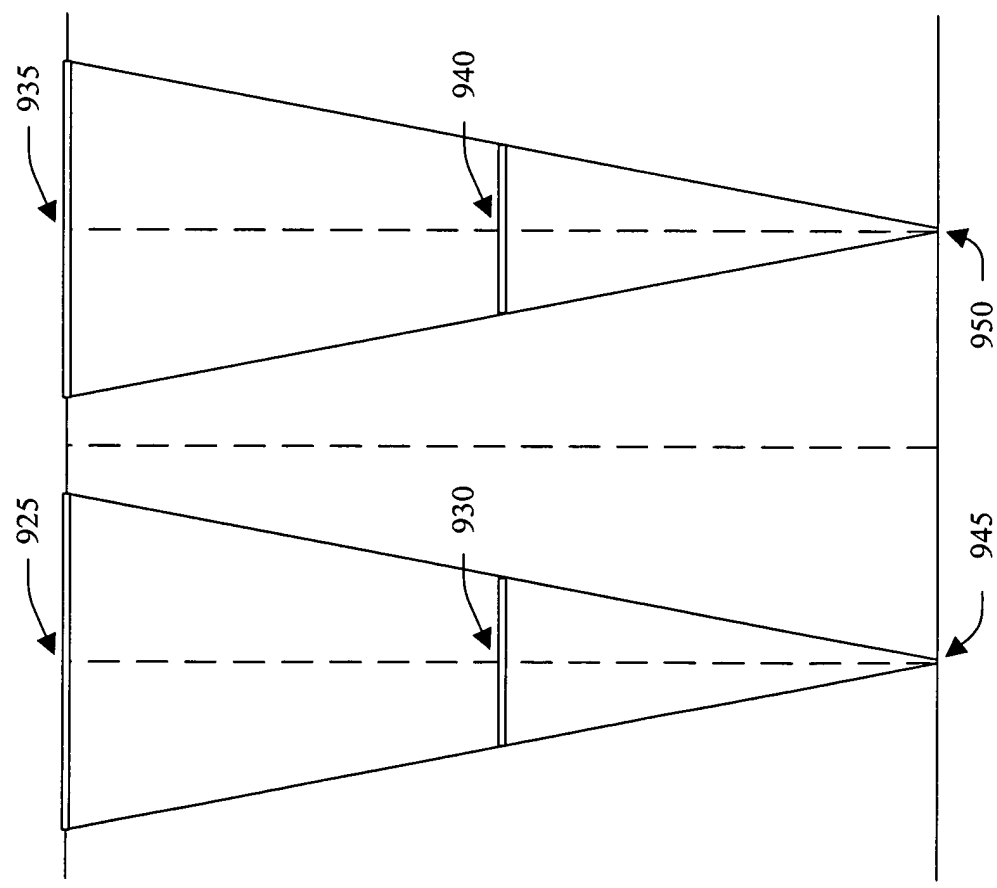
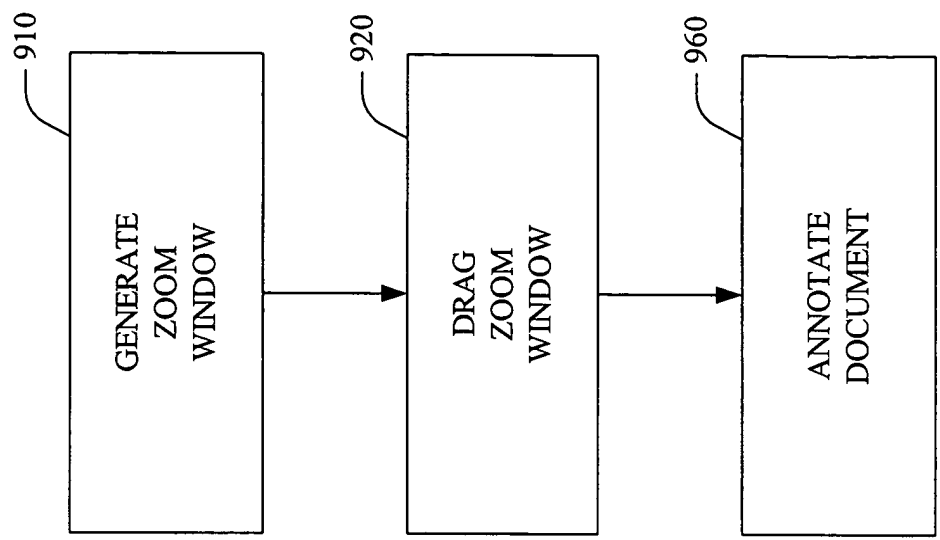


FIG. 9

1000

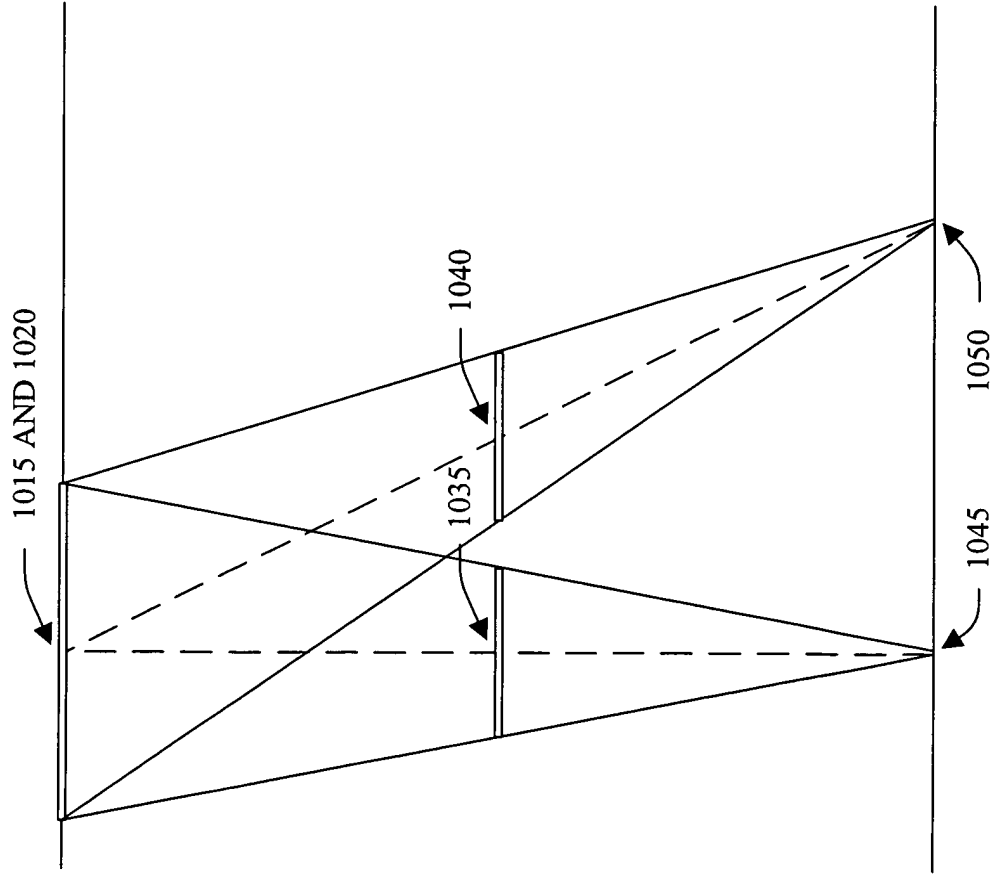
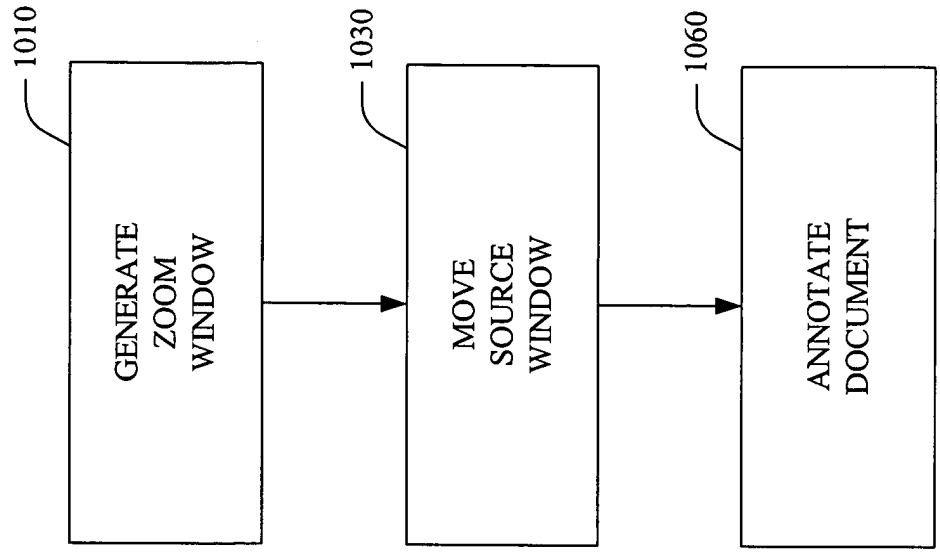


FIG. 10



1100

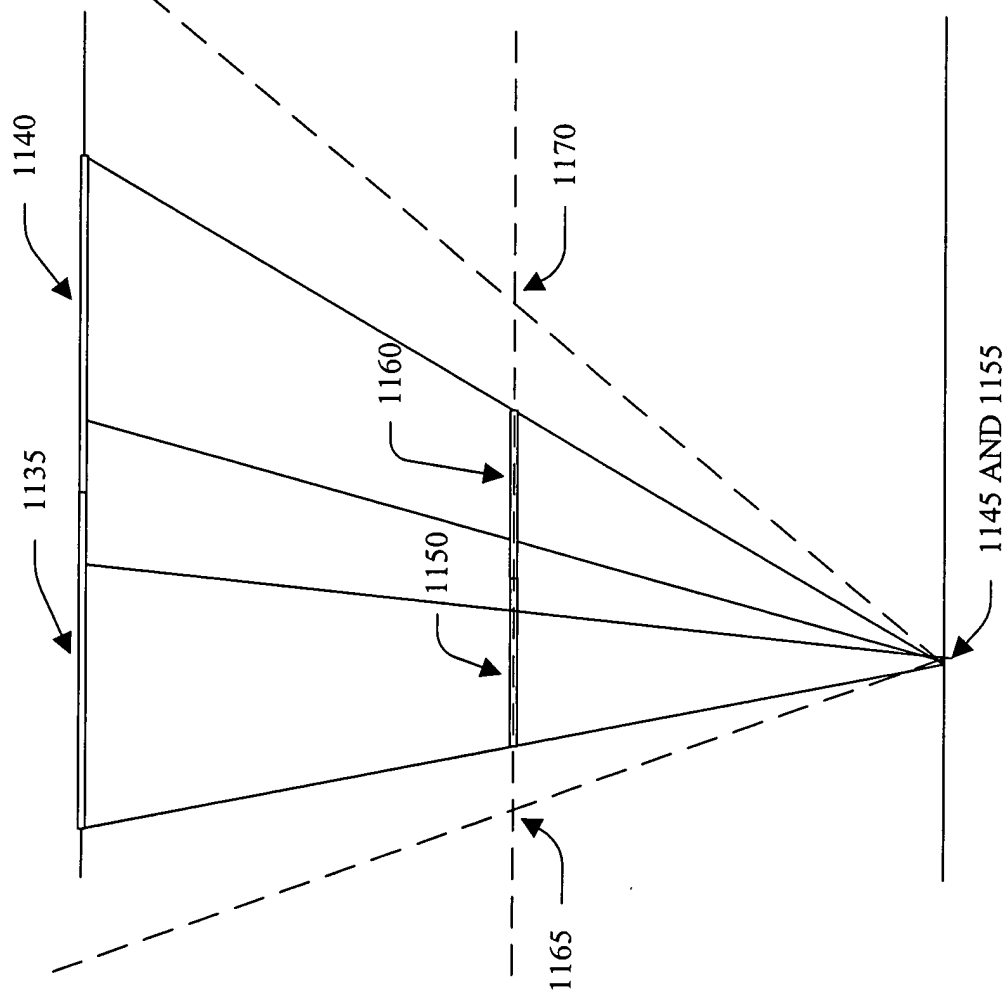
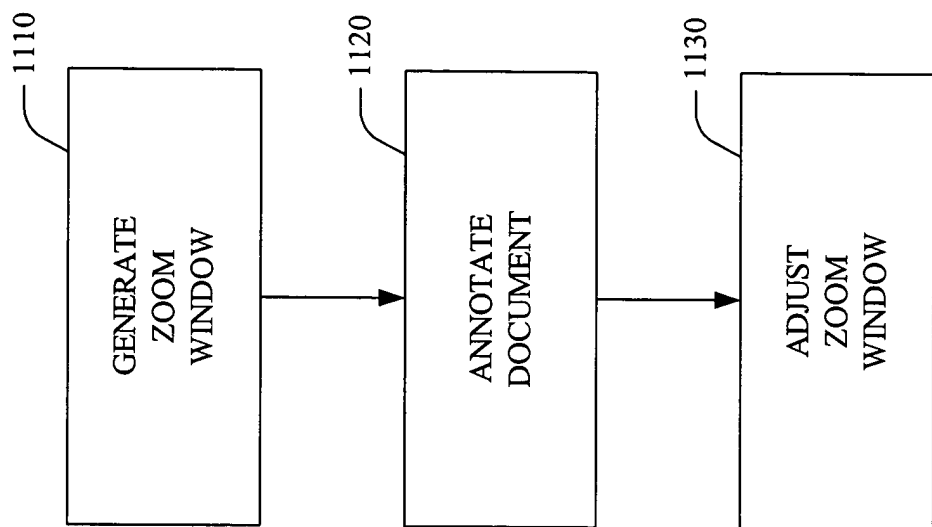
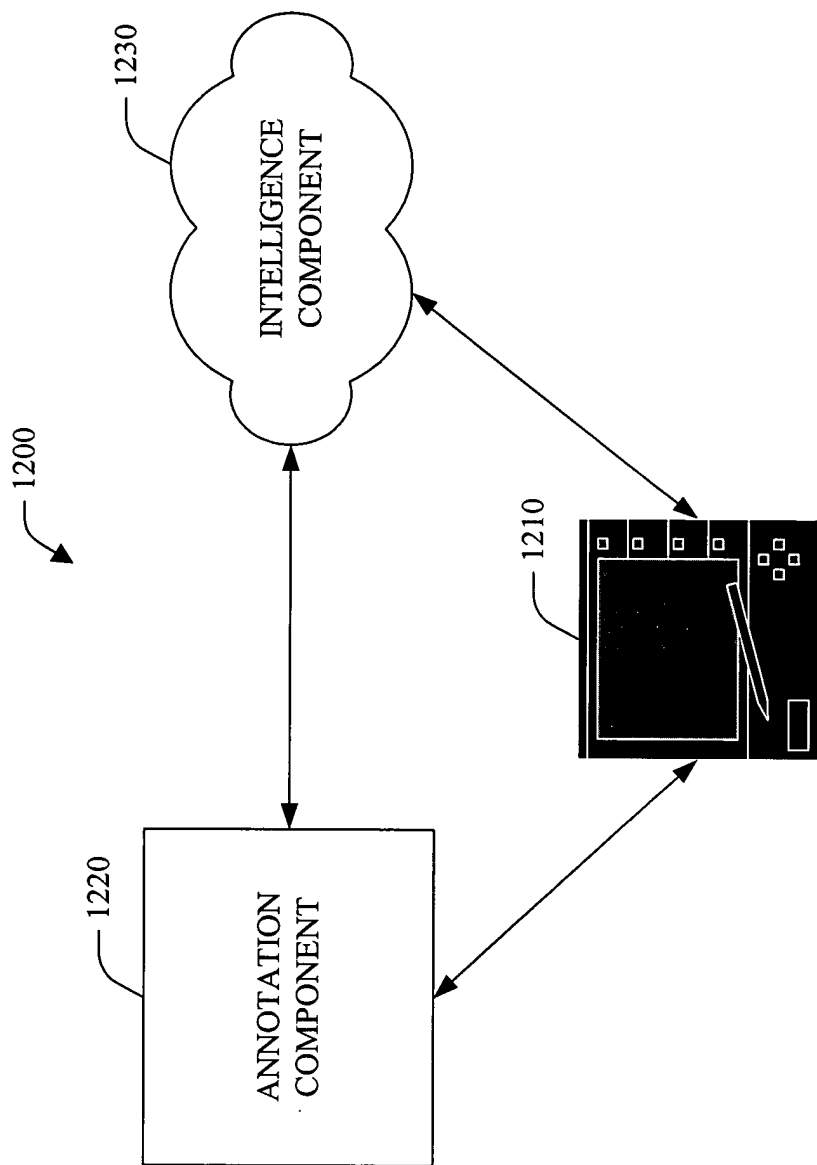


FIG. 11



**FIG. 12**

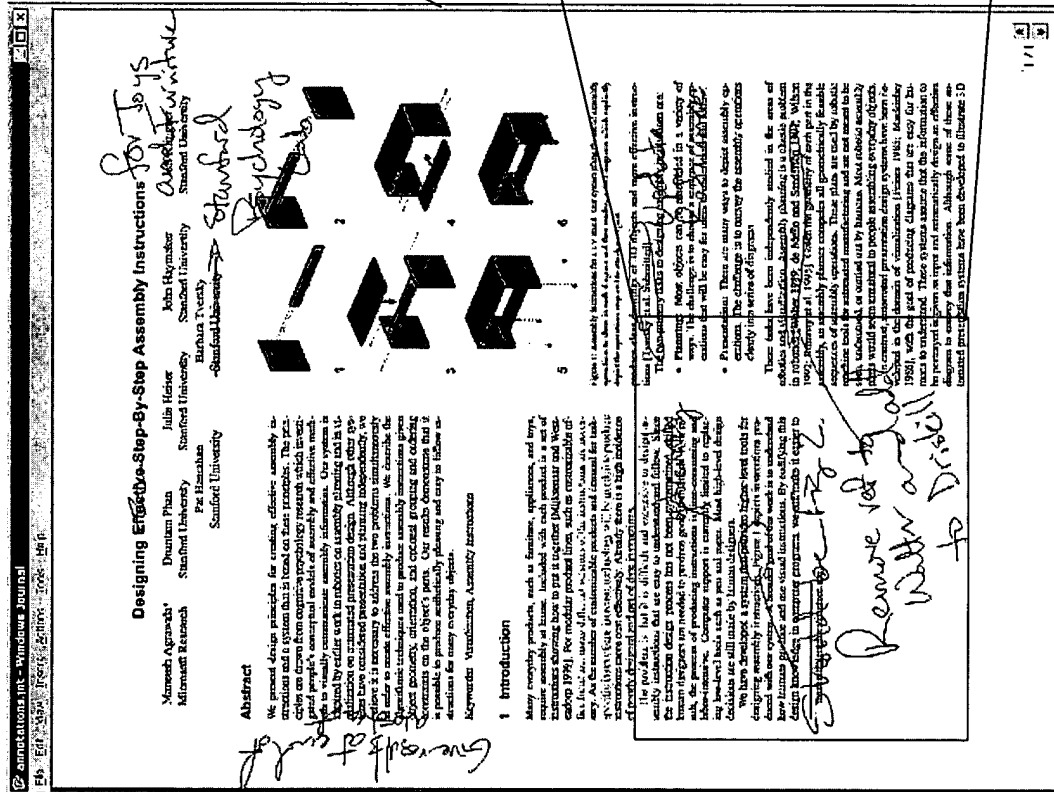


FIG. 13

# Designing Effective Step-By-Step Assembly Instructions for Toys and Furniture

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## Abstract

We present design principles for creating effective assembly instructions and a system that is based on these principles. The principles are drawn from cognitive psychology research which investigated people's conceptual models of assembly and effective methods to visually communicate assembly information. Our system is inspired by earlier work in robotics on assembly planning and in visualization of assembly information. Although other systems have considered presentation design, we believe it is necessary to address the two problems simultaneously in order to create effective assembly instructions. We describe the algorithmic techniques used to produce assembly instructions given object geometry, orientation, and optional grouping and ordering constraints on the object's parts. Our results demonstrate that it is possible to produce aesthetically pleasing and easy to follow instructions for many everyday objects.

**Keywords:** Visualization, Assembly Instructions

## 1 Introduction

Many everyday products, such as furniture, appliances, and toys, require assembly at home. Included with each product is a set of instructions showing how to put it together [Mikve and Westerman 1999]. For modular product lines, such as customizable office furniture, many different versions of the instructions are necessary. These instructions must be easy to understand and follow, and they must be cost-effective. Although there is a high incidence of poorly designed and out-of-date instructions,

the problem is that it is difficult and expensive to design assembly instructions that are easy to understand and follow. Since the instruction design process has not been systematized, skilled human designers are needed to produce good instructions. As a result, the process of producing instructions is time-consuming and labor-intensive. Computer support is currently limited to replacing low-level tools such as pen and paper. Most high-level design decisions are still made by human designers.

We have developed a system that provides higher-level tools for designing assembly instructions (Figure 1). It depicts instructions produced with our system. A broader part of our work is to understand how humans produce and use visual instructions. By codifying this design knowledge in computer programs we can make it easier to

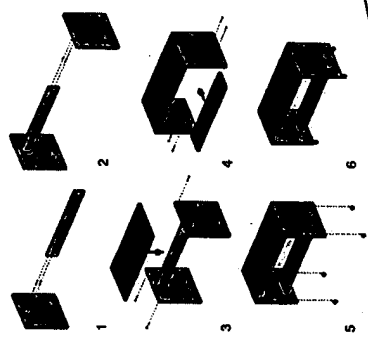


Figure 1: Assembly instructions for a TV stand. The system can be used to automatically generate assembly instructions for a wide range of objects. It depicts the operation required for each step.

presenting a sequence of 3D objects and using effective instructions to guide the user through the assembly process. The very primary tasks in designing assembly instructions are:

- **Planning:** Most objects can be assembled in a variety of ways. The challenge is to select a sequence of operations that will be easy for users to understand and follow.
- **Presentation:** There are many ways to depict assembly operations. The challenge is to convey the assembly operations clearly as a series of diagrams.

These tasks have been independently studied in the areas of robotics and visualization. Assembly planning is a classic problem in robotics [Guthrie 1989, de Mello and Sanderson 1991]. Wilton [1995] has recently proposed a framework for generating sequences of assembly operations. These plans are not meant to be machine tools for automated manufacturing and are not meant to be understood, or carried out by humans. Most robotic assembly plans would seem unnatural to people assembling everyday objects. In contrast, automated presentation design systems have been developed in the domain of visualization [Feiner 1985, Mackinlay 1986], with the goal of producing diagrams that are easy for humans to understand and use. These systems are designed to be portrayed as given as input and automatically design an effective diagram to convey that information. Although some of these automated presentation systems have been developed to illustrate 3D

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FIG. 14

## Designing Effective Step-By-Step Assembly Instructions

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### Abstract

We present design principles for creating effective assembly instructions and a system that is based on these principles. The principles are drawn from cognitive psychology research which investigated people's conceptual models of assembly and effective methods to visually communicate assembly information. Our system is inspired by earlier work in robotics on assembly planning and in visualization on automated presentation design. Although other systems have considered presentation and planning independently, we believe it is necessary to address the two problems simultaneously in order to create effective assembly instructions. We describe the algorithmic techniques used to produce assembly instructions given object geometry, orientation, and optional grouping and ordering constraints on the object's parts. Our results demonstrate that it is possible to produce aesthetically pleasing and easy to follow instructions for many everyday objects.

Keywords: Assembly instructions

### 1 Introduction

Many everyday products, such as furniture, require assembly at home. Included with each product are instructions showing how to put it together (Miksemur and Endrop 1999). For modular product lines, such as customizable office furniture, many different versions of the instructions are necessary. As the number of customizable products and demand for task-specific instructions increase, technology will be needed to produce instructions more cost effectively. Already there is a high incidence of poorly designed and out of date instructions.

The problem is that it is difficult and expensive to design assembly instructions that are easy to understand and follow. Since the instruction design process has not been systematized, skilled human designers are needed to produce good instructions. As a result, the process of producing instructions is time-consuming and labor-intensive. Computer support is currently limited to replacing low-level tools such as pen and paper. Most high-level design decisions are still made by human designers.

We have developed a system that provides higher-level tools for designing assembly instructions. Figure 1 depicts instructions produced with our system. A broader goal of our work is to understand how humans produce and use visual instructions. By codifying this design knowledge in computer programs we can make it easier to

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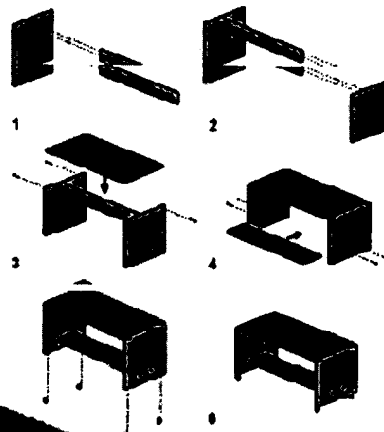


Figure 1: Assembly instructions for a TV stand. Our system plans the set of assembly operations to show in the diagrams and then renders action diagrams which helpfully depict the operations required to assemble the part.

produce clear drawings of 3D objects and more effective instructions (Tversky et al. Submitted).

The two primary tasks in designing assembly instructions are:

- **Planning:** Most objects can be assembled in a variety of ways. The challenge is to choose a sequence of assembly operations that will be easy for users to understand and follow.
- **Presentation:** There are many ways to depict assembly operations. The challenge is to convey the assembly operations clearly in a series of diagrams.

These tasks have been independently studied in the areas of robotics and visualization. Assembly planning is a classic problem in robotics (Wilner 1980; de Mello and Sanghavi 1981; Wilner 1982; Romney et al. 1995). Given the geometry of each part in the assembly, an assembly planner computes all geometrically feasible sequences of assembly operations. These plans are used by robotic machine tools for automated manufacturing and are not meant to be seen, understood, or carried out by humans. Most robotic assembly plans would seem unnatural to people assembling everyday objects.

In contrast, automated presentation design systems have been developed in the domain of visualization (Feiner 1983; Mackinlay 1986) with the goal of producing diagrams that are easy for humans to understand. These systems assume that the information to be portrayed is given as input and automatically design an effective diagram to convey that information. Although some of these automated presentation systems have been developed to illustrate 3D

FIG. 15

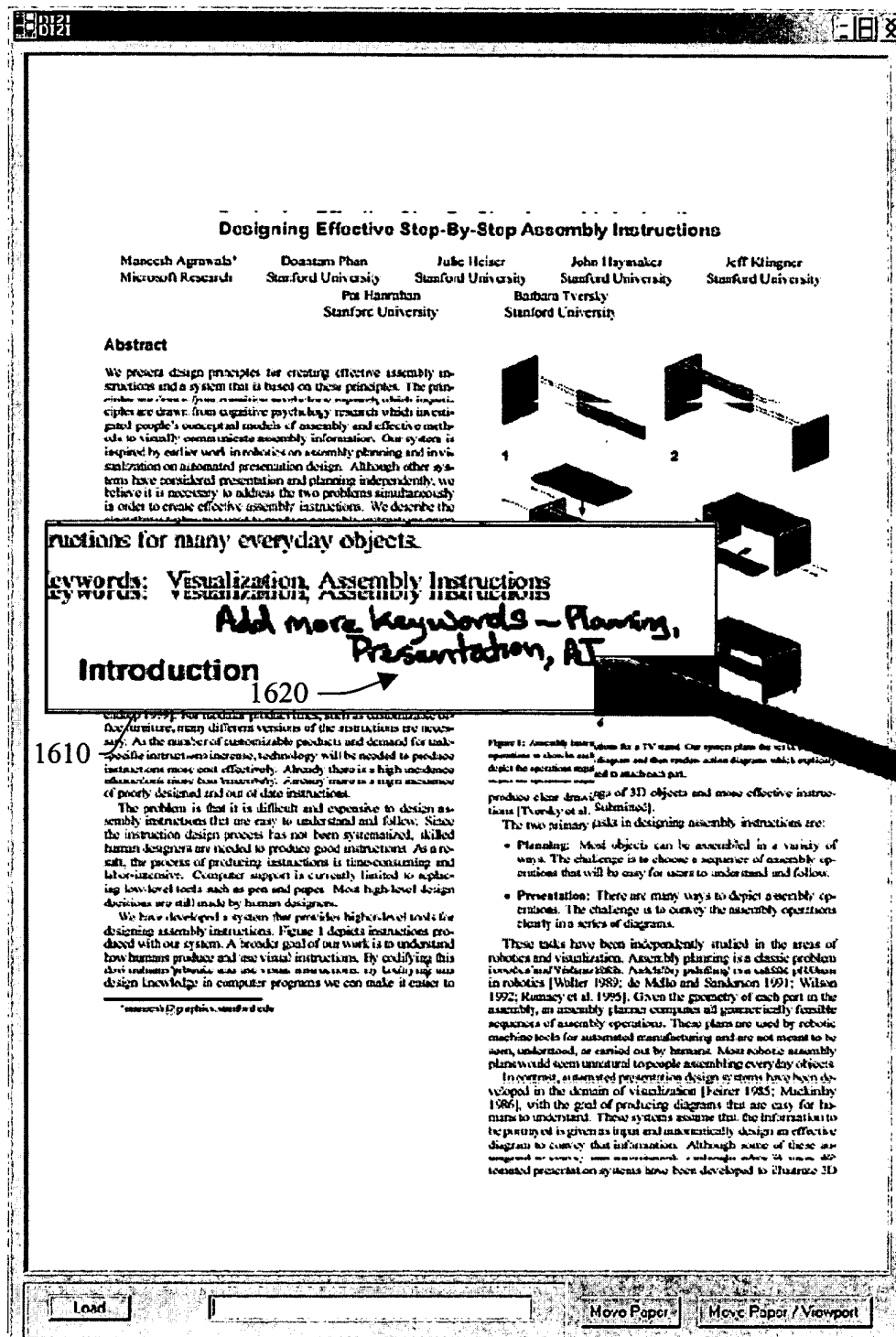


FIG. 16

## Designing Effective Step-By-Step Assembly Instructions

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### Abstract

We present design principles for creating effective assembly instructions and a system that is based on these principles. The principles are drawn from cognitive psychology research which investigated people's conceptual models of assembly and effective methods to visually communicate assembly information. Our system is inspired by earlier work in robotics on assembly planning and in visualization on automated presentation design. Although other systems have considered presentation and planning independently, we believe it is necessary to address the two problems simultaneously in order to create effective assembly instructions. We describe the algorithmic techniques used to produce assembly instructions given object geometry, orientation, and optional grouping and ordering constraints on the object's parts. Our results demonstrate that it is possible to produce aesthetically pleasing and easy to follow instructions for many everyday objects.

Keywords: Visualization, Assembly Instructions

*Add more keywords - Planning, Presentation, AI*

### 1 Introduction

Many everyday products, such as furniture, appliances, and toys, require assembly at home. Included with each product is a set of instructions showing how to put it together [Mijksenaar and Westendorp 1999]. For modular product lines, such as customizable office furniture, many different versions of the instructions are necessary. As the number of customizable products and demand for task-specific instructions increase, technology will be needed to produce instructions more cost effectively. Already there is a high incidence of poorly designed and out of date instructions.

The problem is that it is difficult and expensive to design assembly instructions that are easy to understand and follow. Since the instruction design process has not been systematized, skilled human designers are needed to produce good instructions. As a result, the process of producing instructions is time-consuming and out, the process of producing instructions is time-consuming and labor-intensive. Computer support is currently limited to replacing low-level tools such as pen and paper. Most high-level design decisions are still made by human designers.

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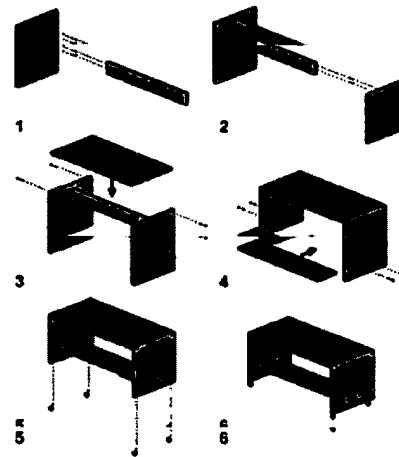


Figure 1: Assembly instructions for a TV stand. Our system plans the set of assembly operations to show in each diagram and then renders action diagrams which explicitly depict the operations required to attach each part.

produce clear drawings of 3D objects and more effective instructions [Tversky et al. Submitted].

The two primary tasks in designing assembly instructions are:

- **Planning:** Most objects can be assembled in a variety of ways. The challenge is to choose a sequence of assembly operations with advantages or disadvantages in complexity or time that will be easy for users to understand and follow.
- **Presentation:** There are many ways to depict assembly operations. The challenge is to convey the assembly operations clearly in a series of diagrams.

These tasks have been independently studied in the areas of robotics and visualization. Assembly planning is a classic problem in robotics [Wolter 1989; de Mello and Sanderson 1991; Wilson 1992; Romney et al. 1995]. Given the geometry of each part in the assembly, an assembly planner computes all geometrically feasible sequences of assembly operations. These plans are used by robotic sequences of assembly operations. These plans are used by robotic machine tools for automated manufacturing and are not meant to be seen, understood, or carried out by humans. Most robotic assembly plans would seem unnatural to people assembling everyday objects.

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FIG. 17

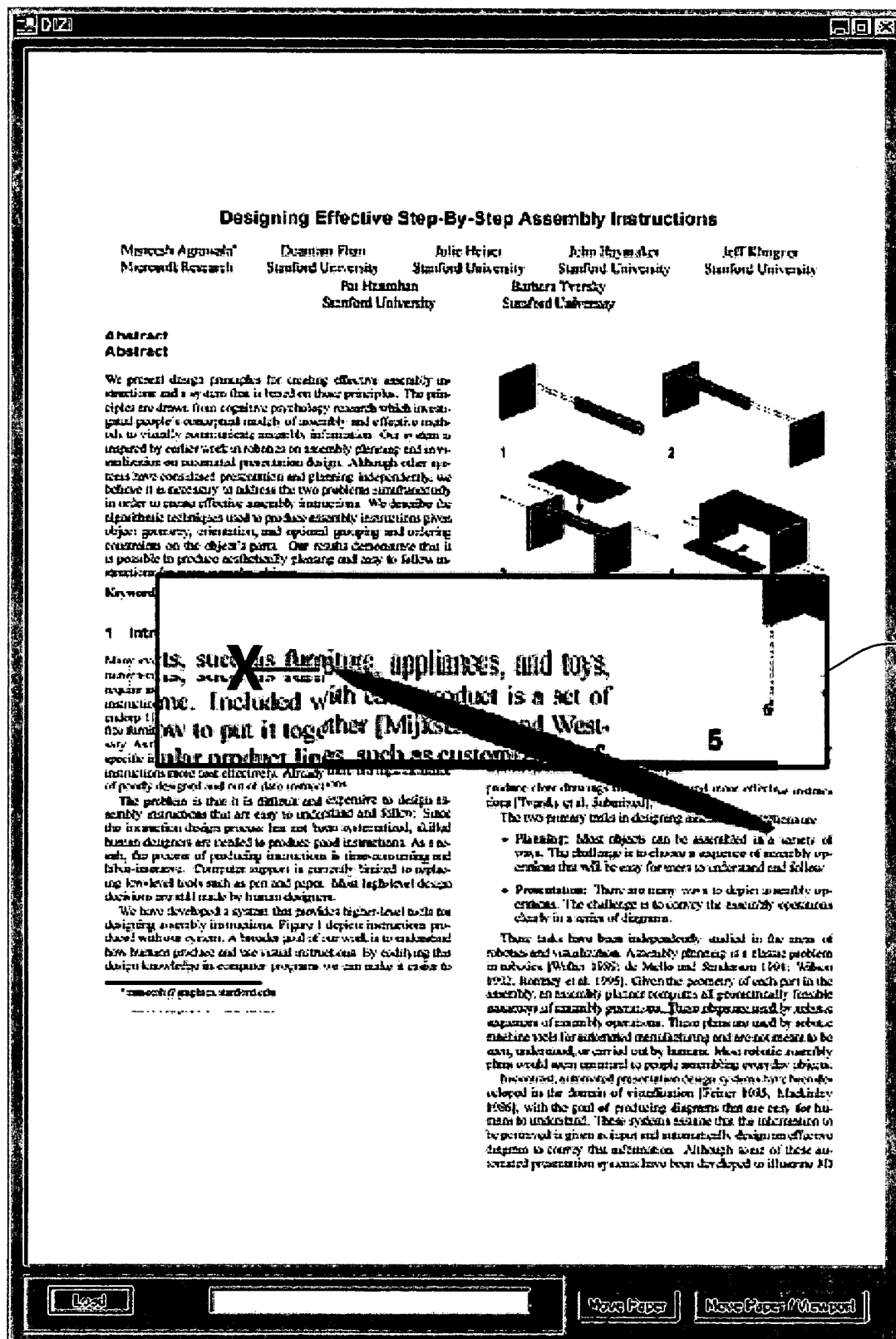


FIG. 18



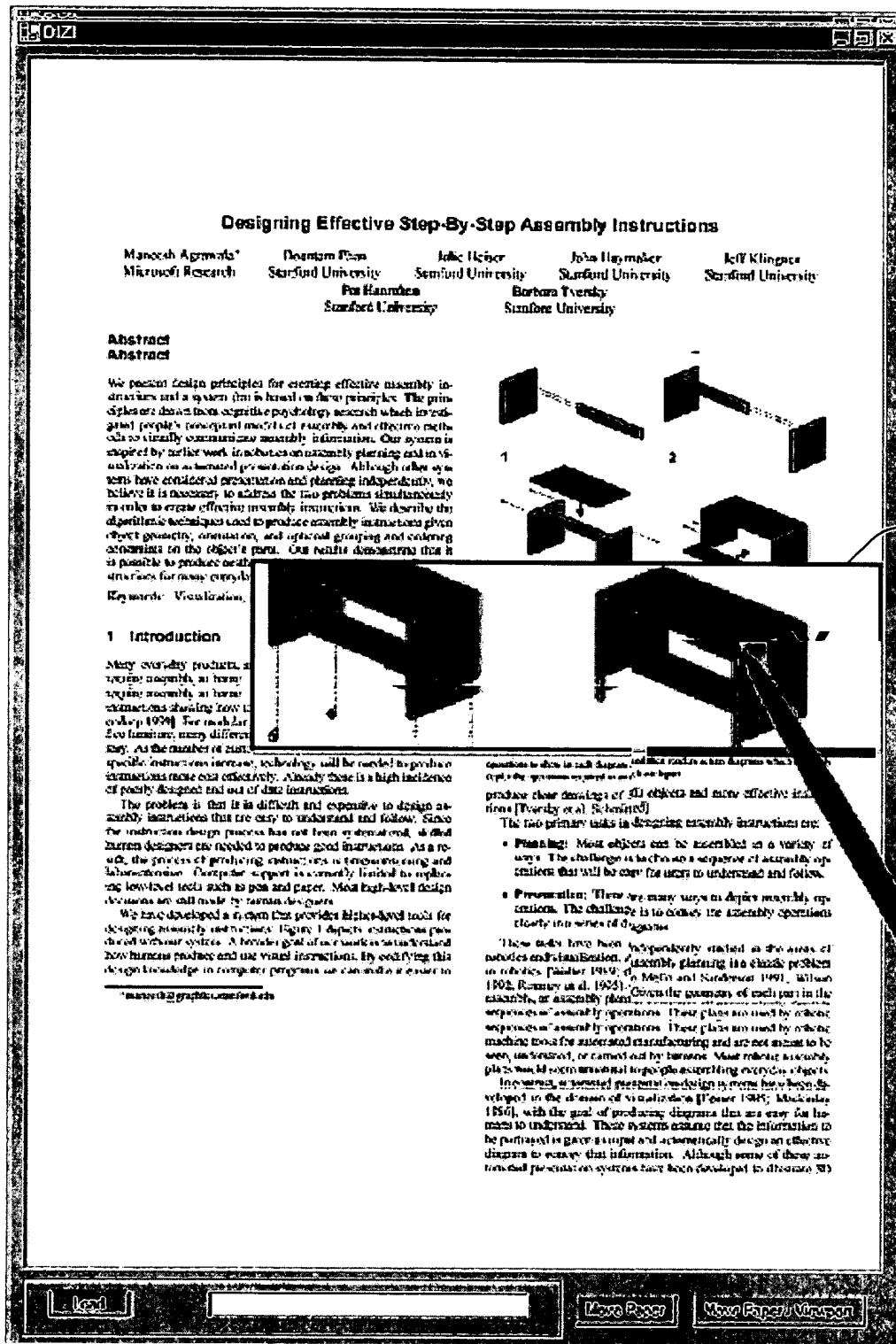


FIG. 19

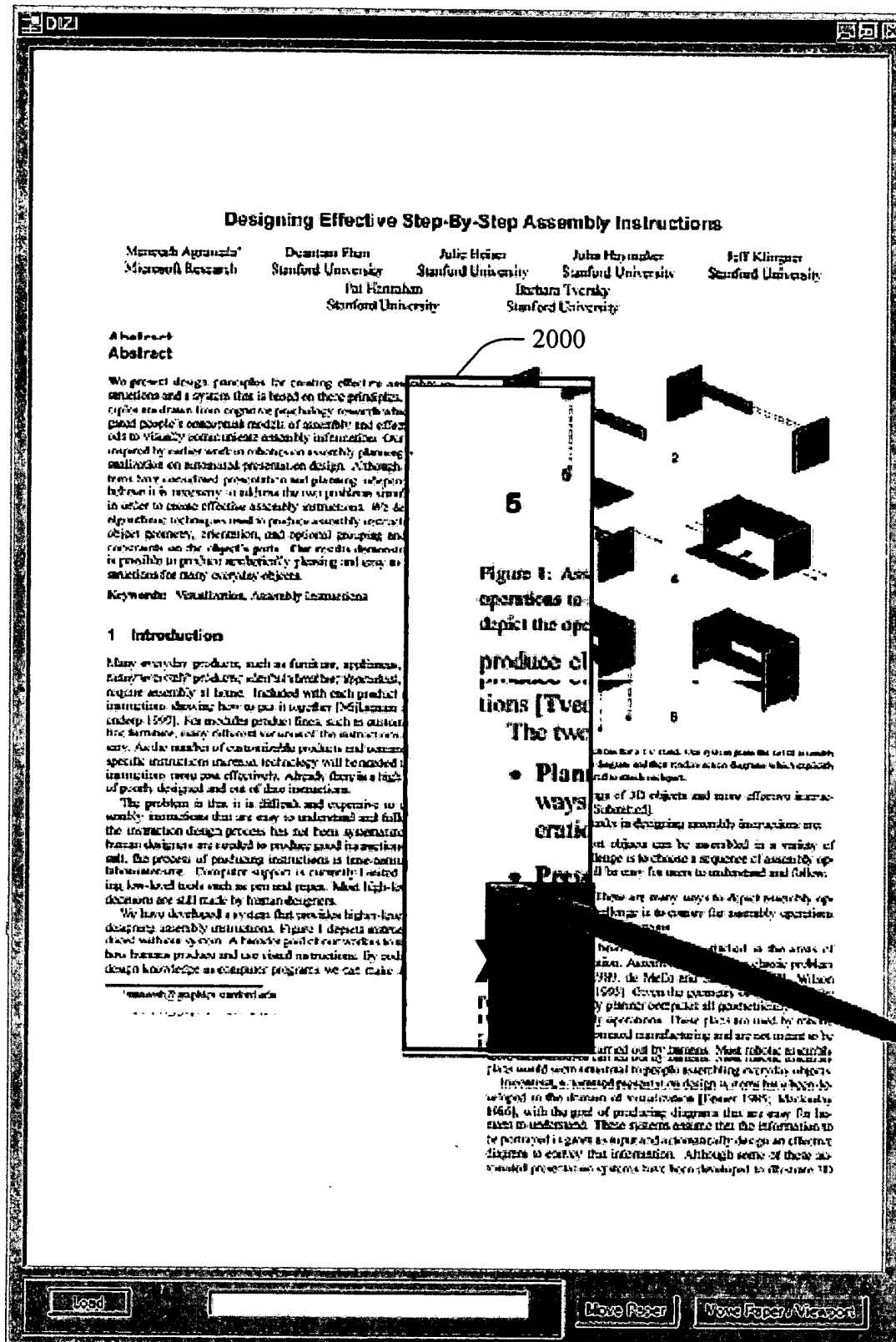
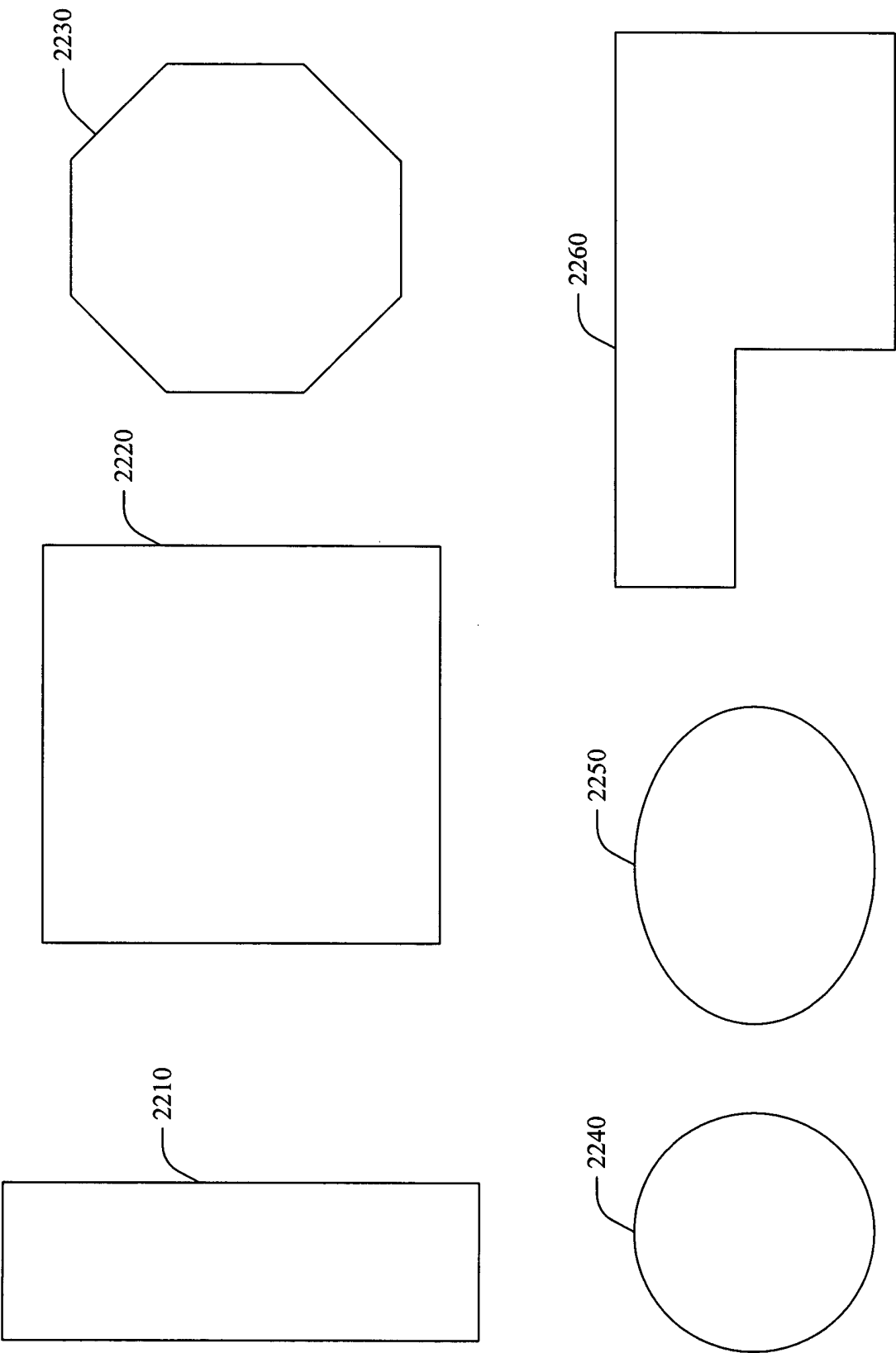
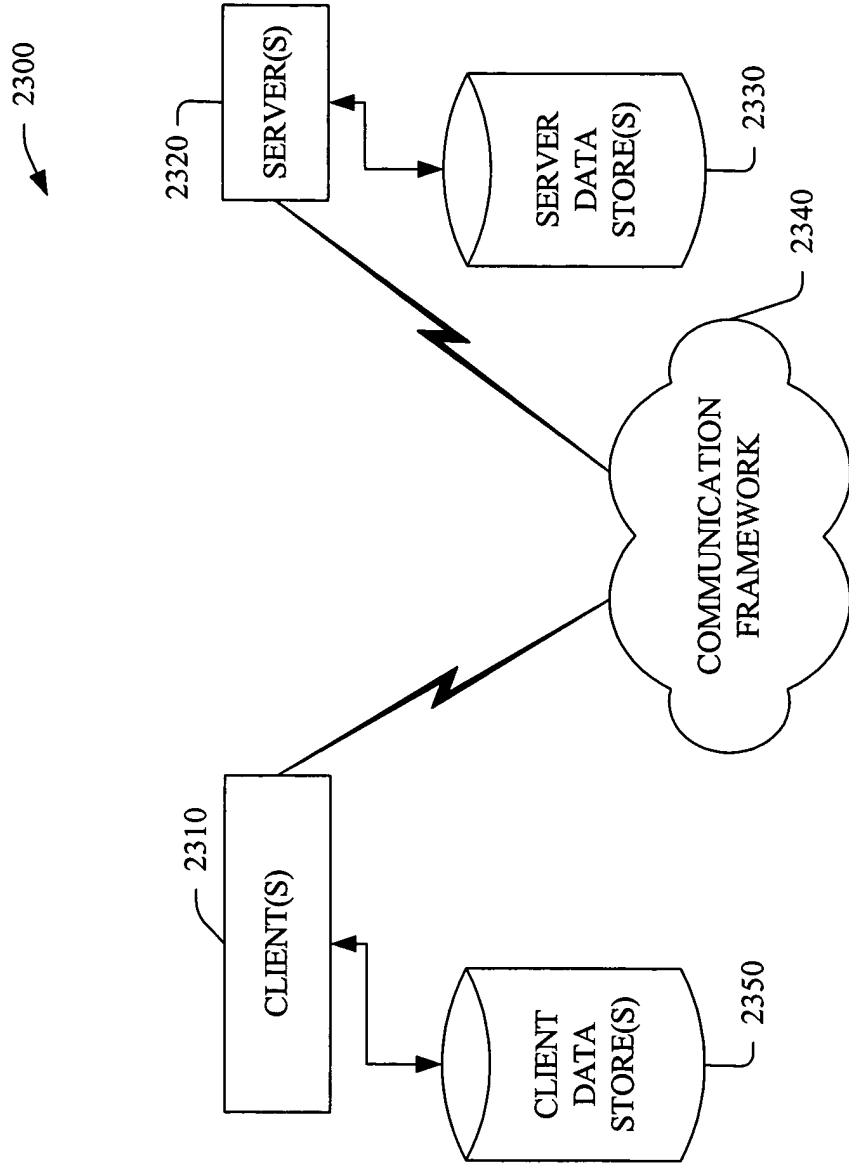


FIG. 20

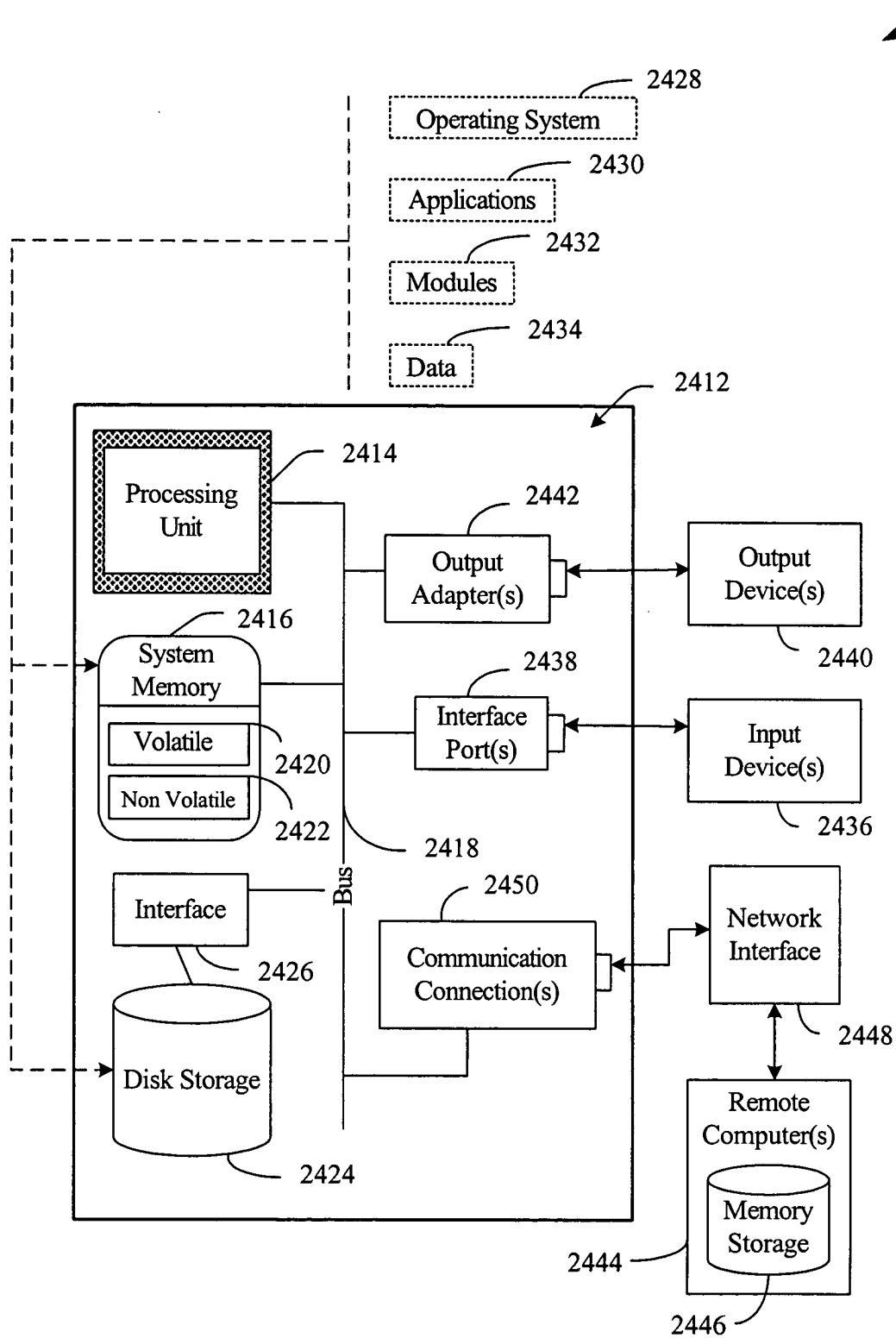




**FIG. 22**



**FIG. 23**



**FIG. 24**